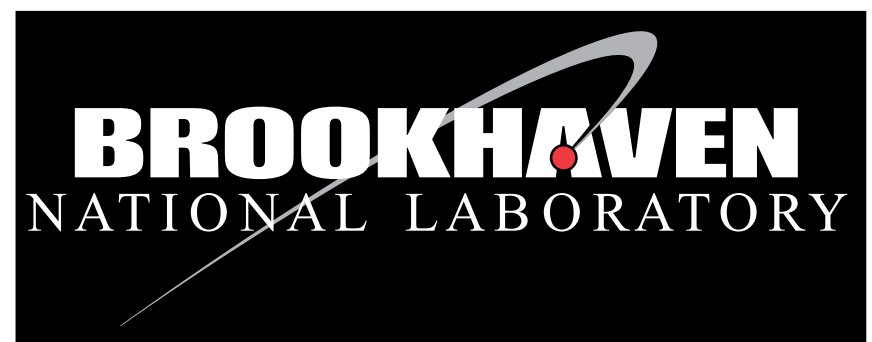# The eRHIC project

Thomas Burton
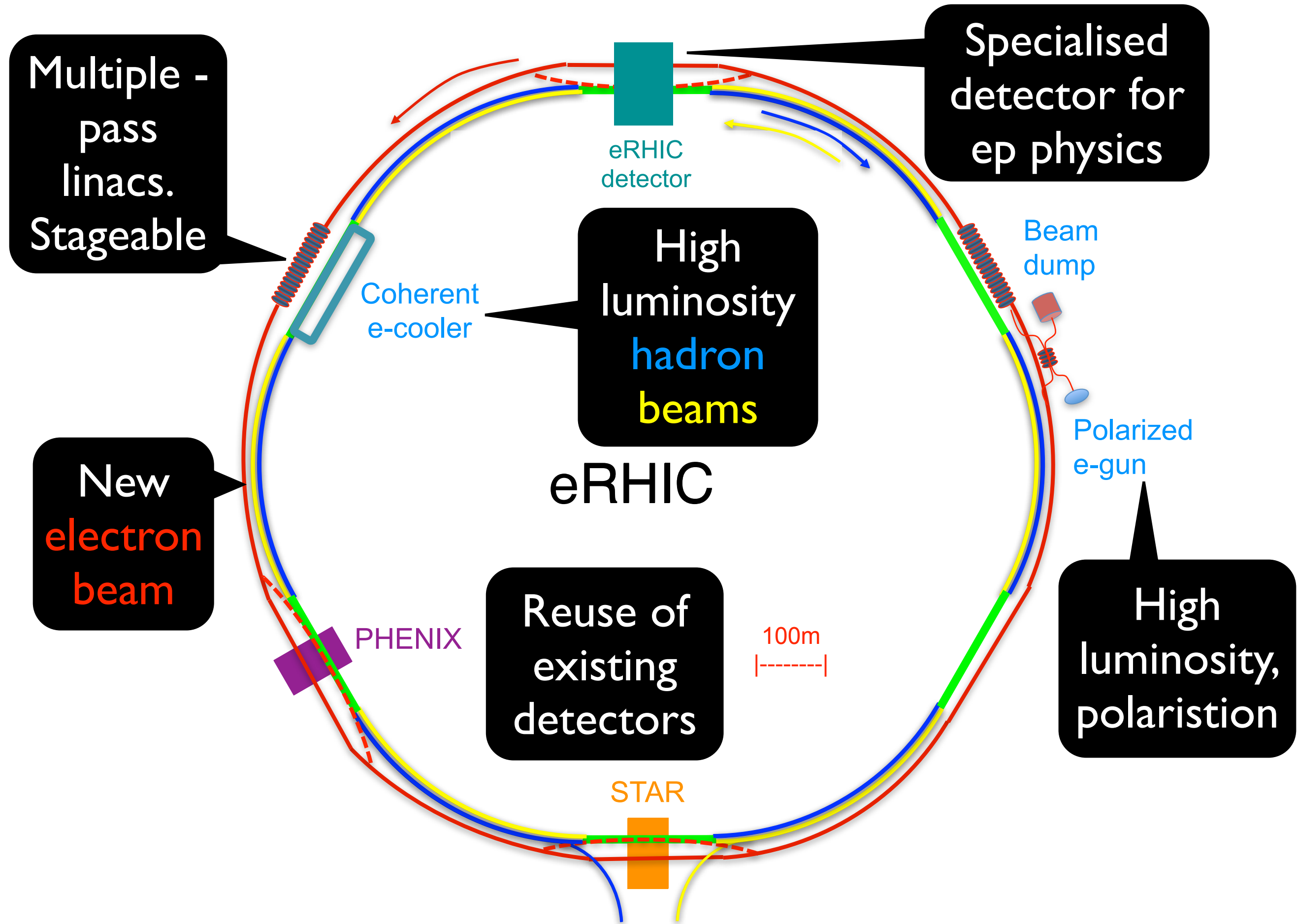Brookhaven National Lab
International Conference on Frontiers in Physics
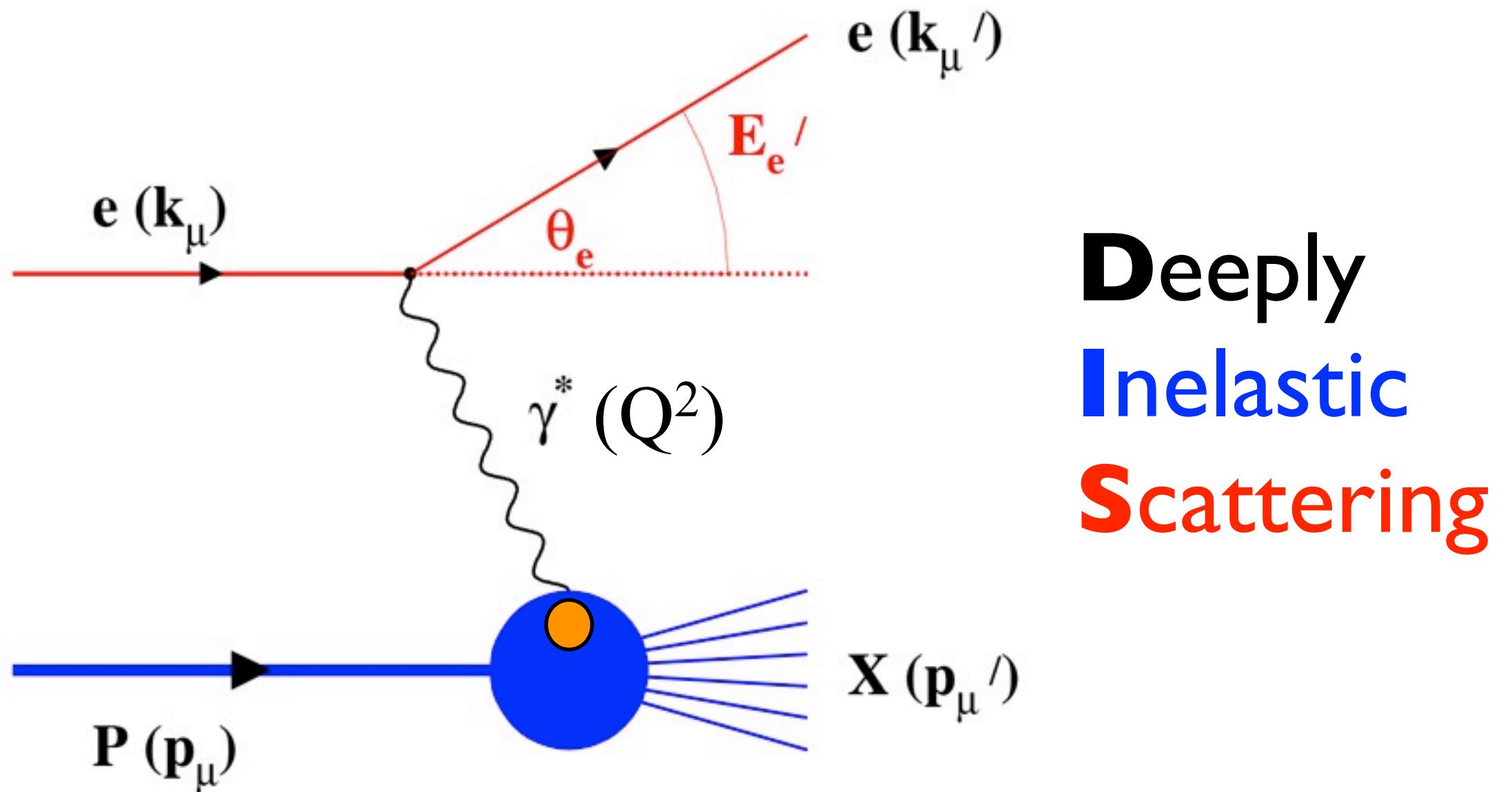
I

The **eRHIC** project

- BNL's proposal for an **Electron-ion-collider**

- Next-gen facility for nucle(on/ar) structure

  ▸ Extreme luminosity

  ▸ Variable beam energies

  ▸ Multiple ion species: p to U

  ▸ Polarised beams

Multiple - pass linacs. Stageable

Specialised detector for ep physics

High luminosity hadron beams

Coherent e-cooler

eRHIC detector

Beam dump

Polarized e-gun

New electron beam

High luminosity, polaristion

Reuse of existing detectors

100m
|-------|

PHENIX

STAR

eRHIC

3

Probing hadrons: **DIS**

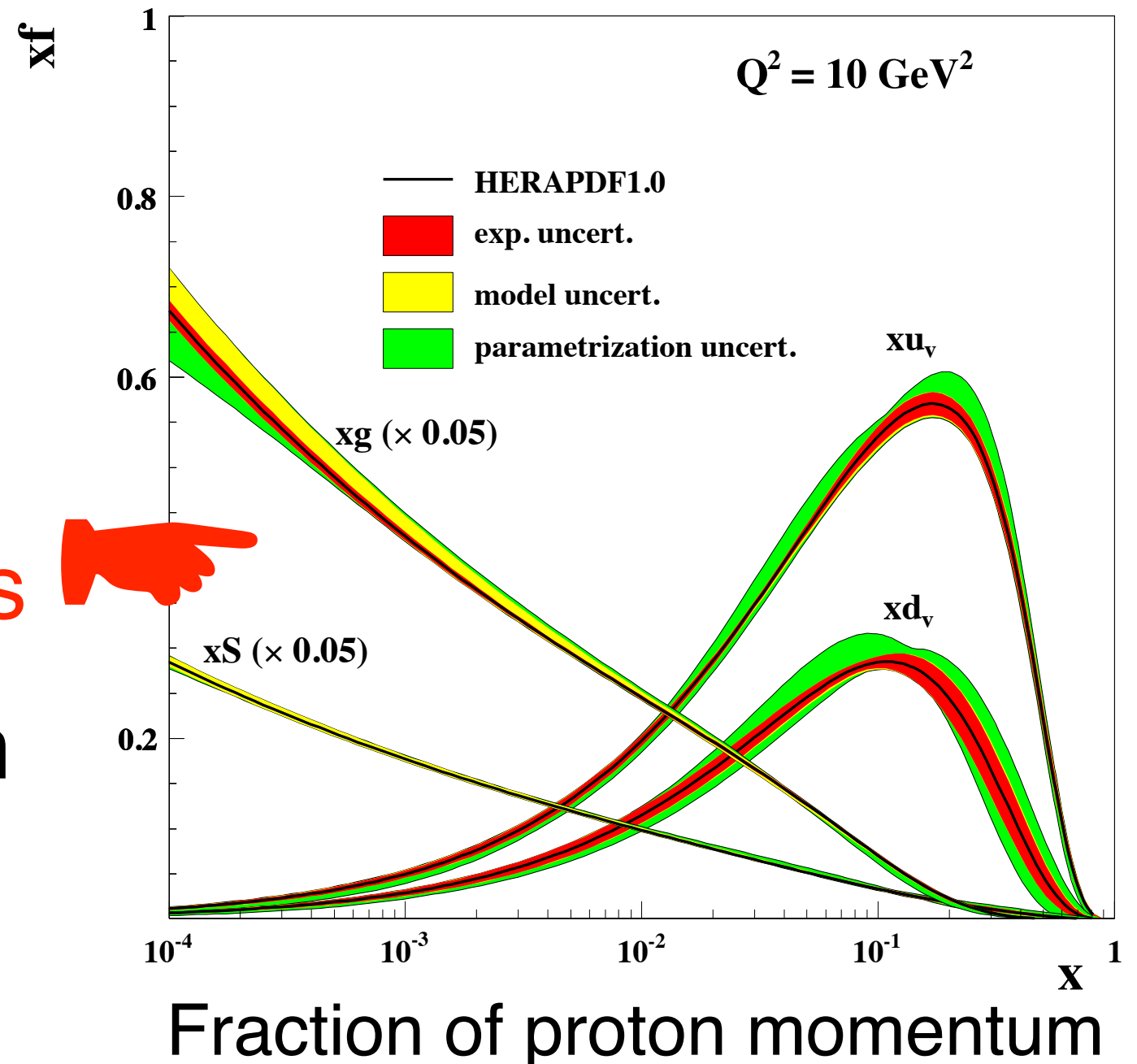**D**eeply
Inelastic
Scattering

- Photon interacts with **quark** not **proton**

- Clean probe of nucleon

4

Proton structure

$$\sigma_r = \boxed{F_2(x, Q^2)} - \frac{y^2}{1 + (1-y)^2} \boxed{F_L(x, Q^2)}$$

- Describable with structure functions

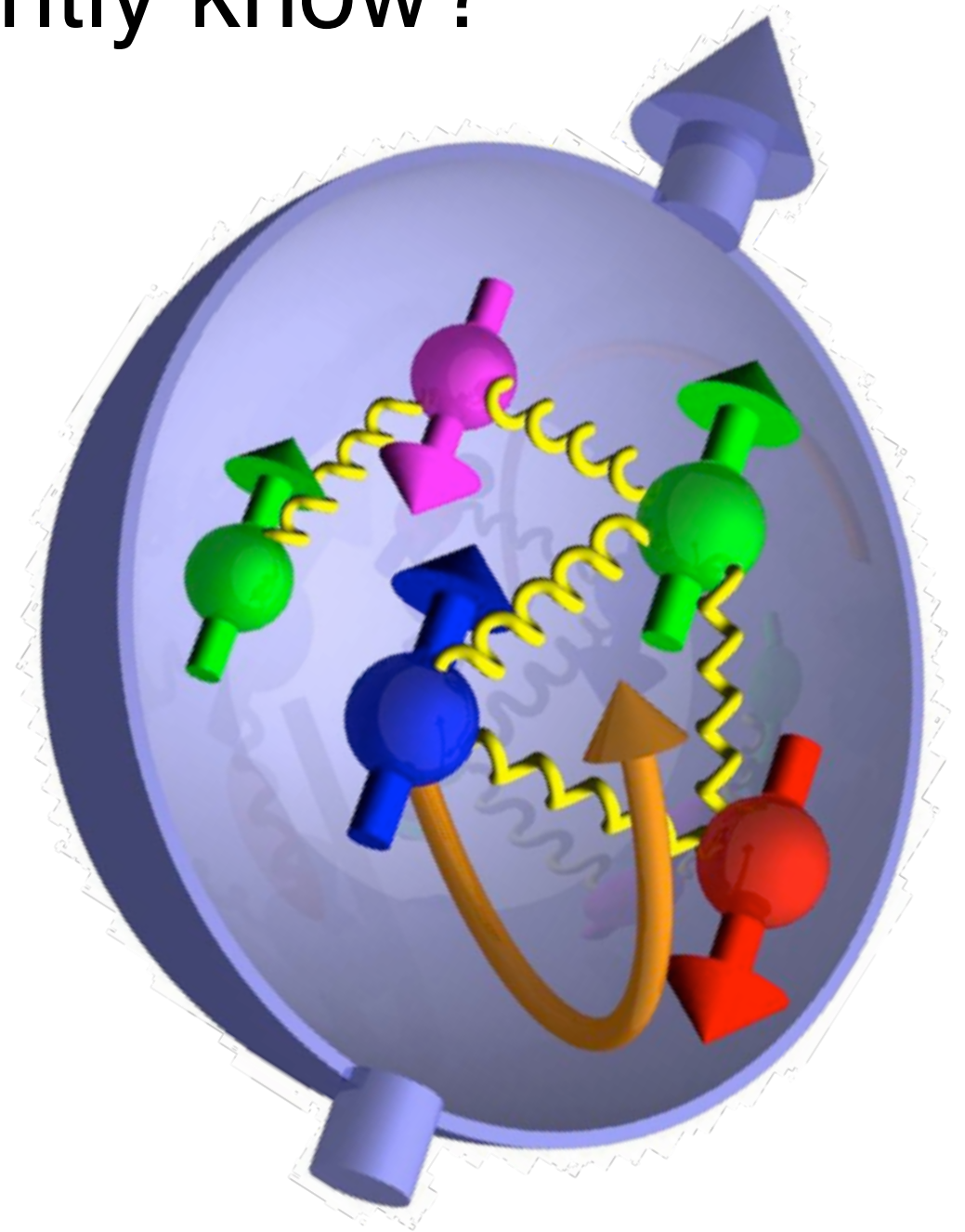- Relate to parton distribution functions

  ▸ parton momentum inside proton

H1 and ZEUS

$Q^2 = 10$ GeV^2

— HERAPDF1.0
█ exp. uncert.
█ model uncert.
█ parametrization uncert.

$xg \ (\times 0.05)$

xu_v

xd_v

$xS \ (\times 0.05)$

Fraction of proton momentum

1: Spin physics

DIS with **polarised** beams

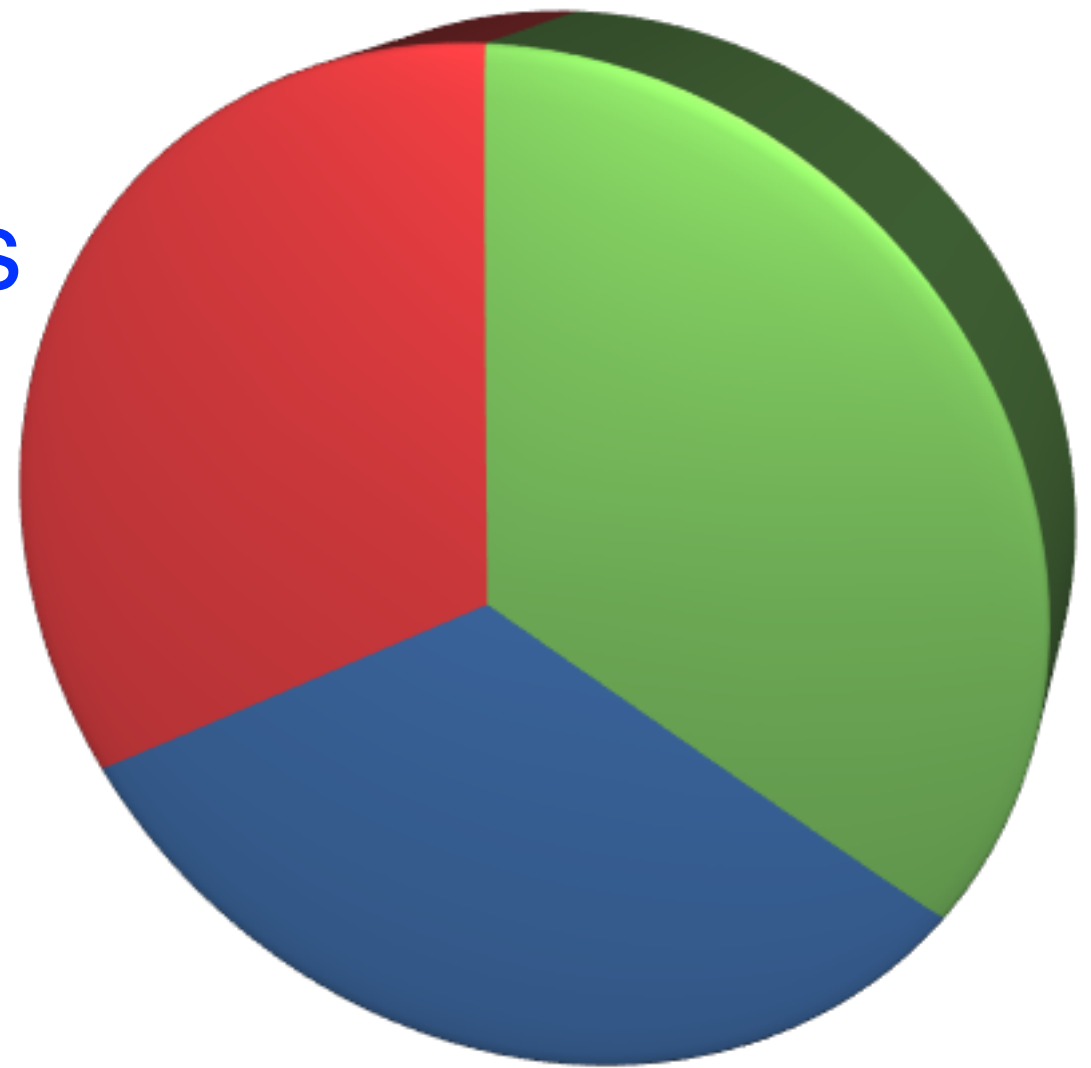Allows study of nucleon spin
What do we currently know?

DIS with polarised beams

Allows study of nucleon spin
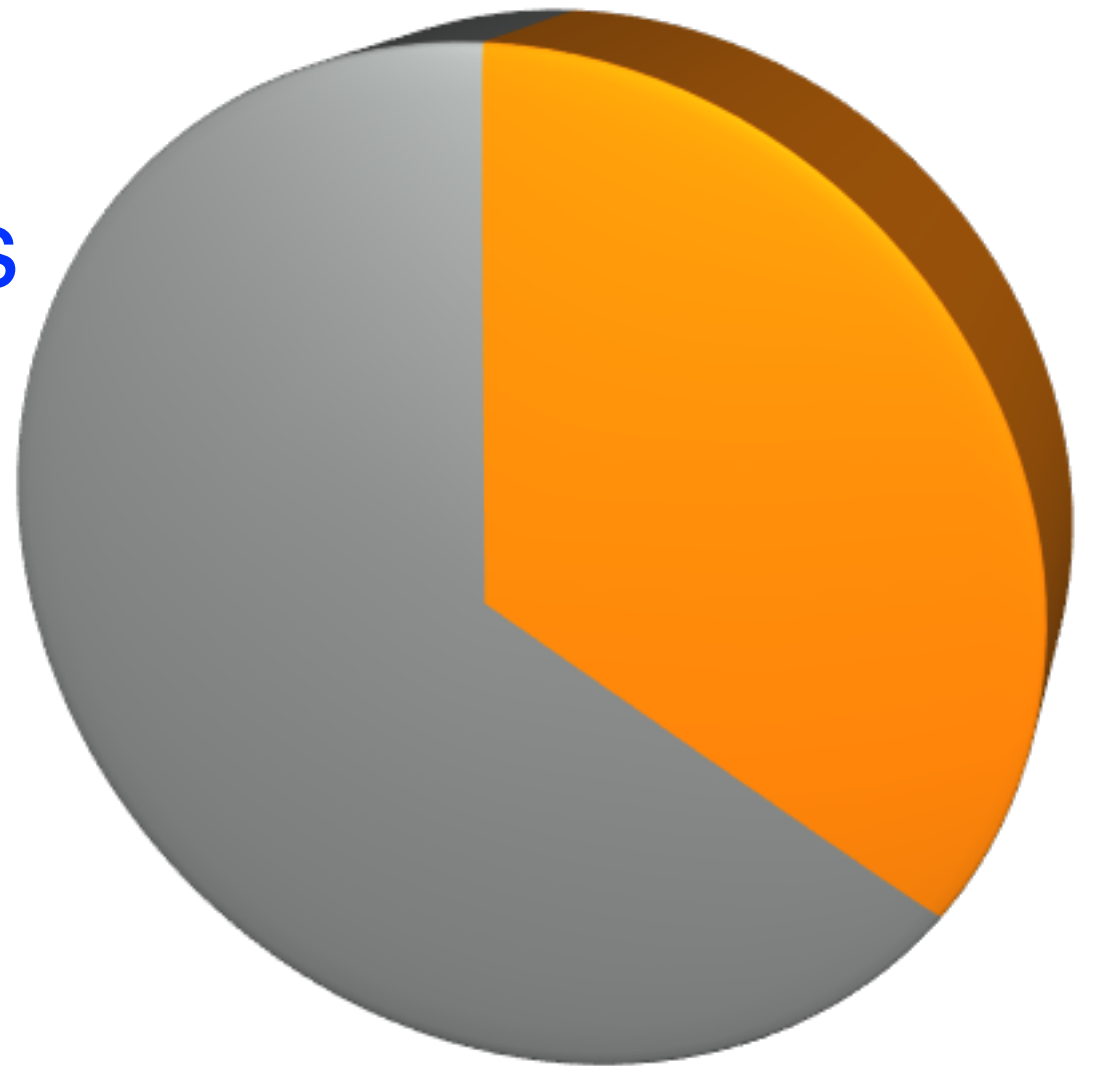What do we currently know?

- **Not** from 3 spin ½ quarks

DIS with polarised beams
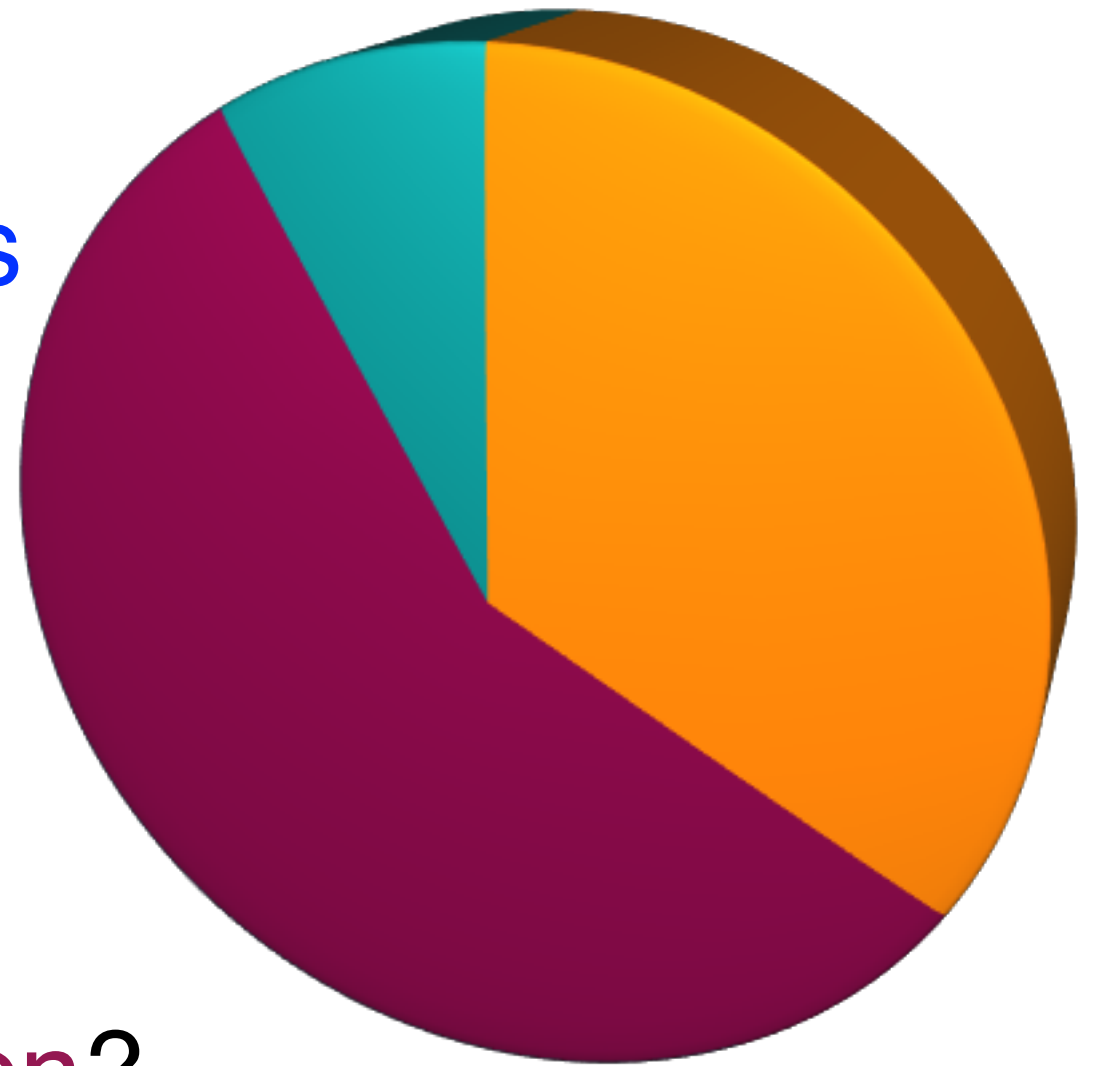
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- **Not** from 3 spin ½ quarks

- Only ⅓ from quark spin

- Remainder unclear

DIS with polarised beams

Allows study of nucleon spin
What do we currently know?

- **Not** from 3 spin ½ quarks
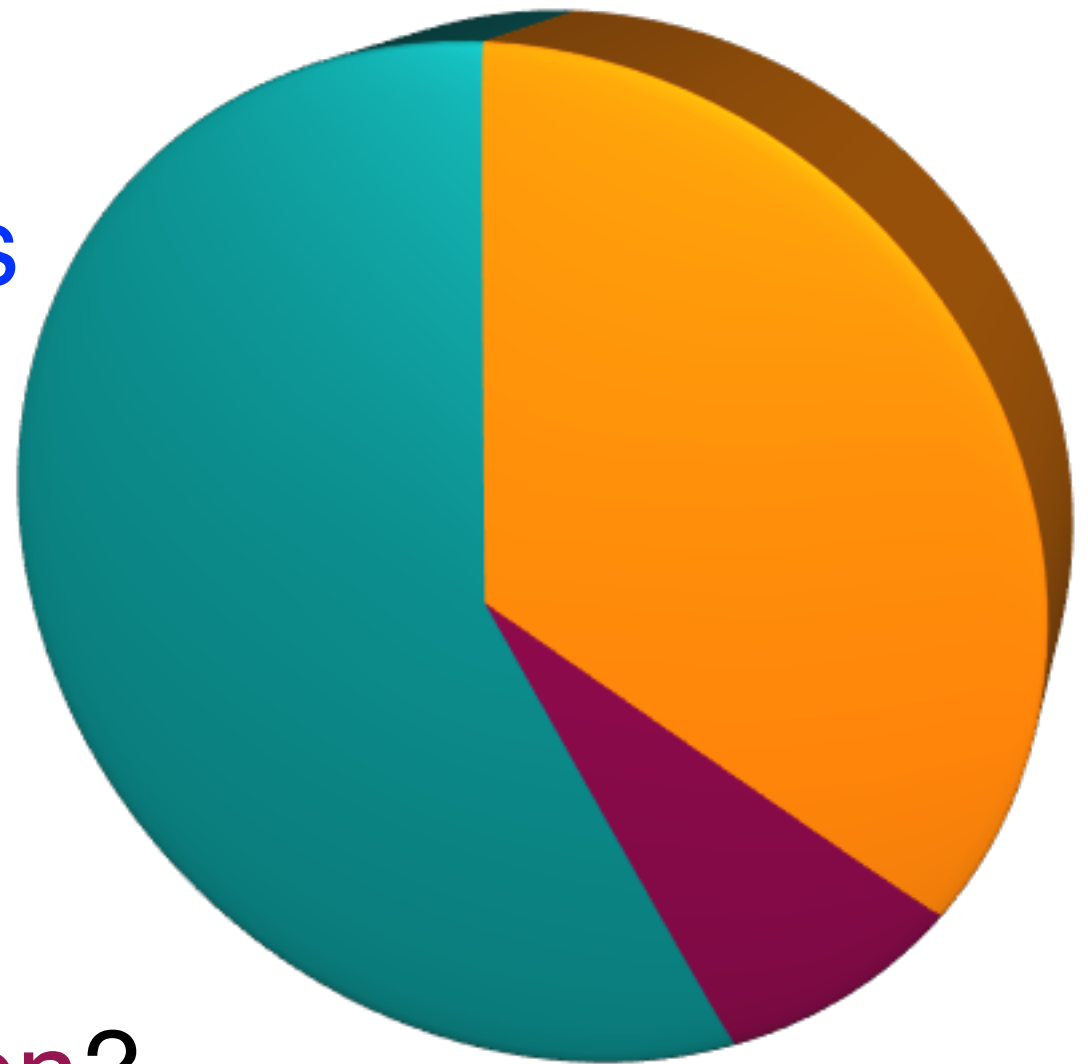
- Only ⅓ from quark spin
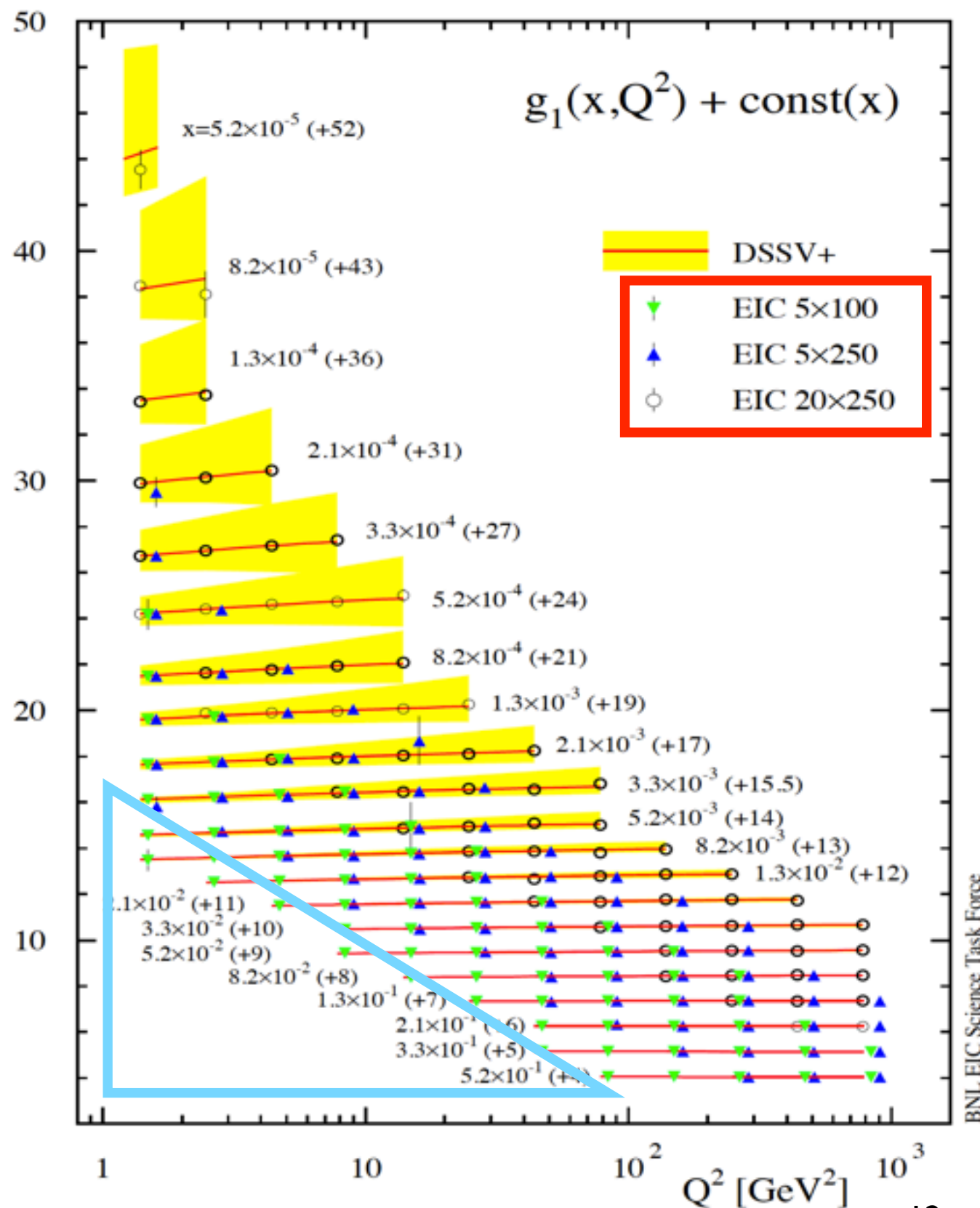
- Remainder unclear

  ‣ How much gluon spin?

  ‣ How much orbital motion?

DIS with polarised beams

Allows study of nucleon spin
What do we currently know?

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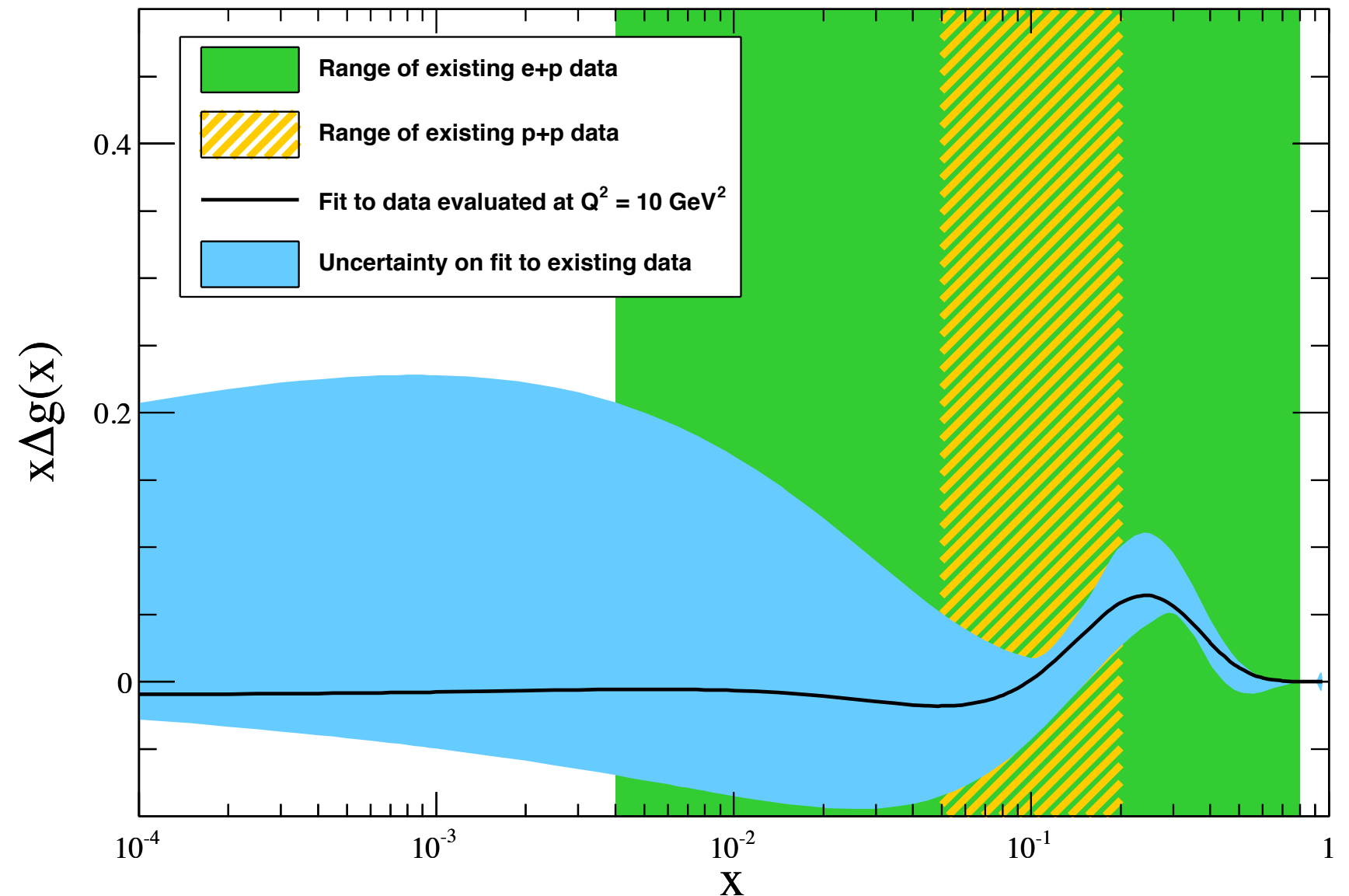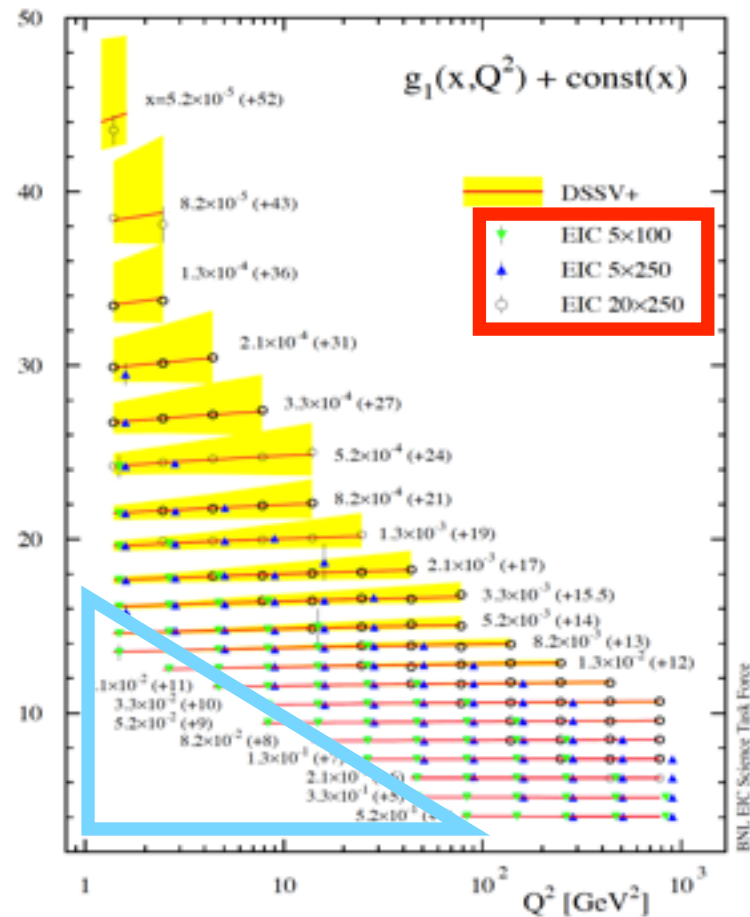 ▸ How much gluon spin?

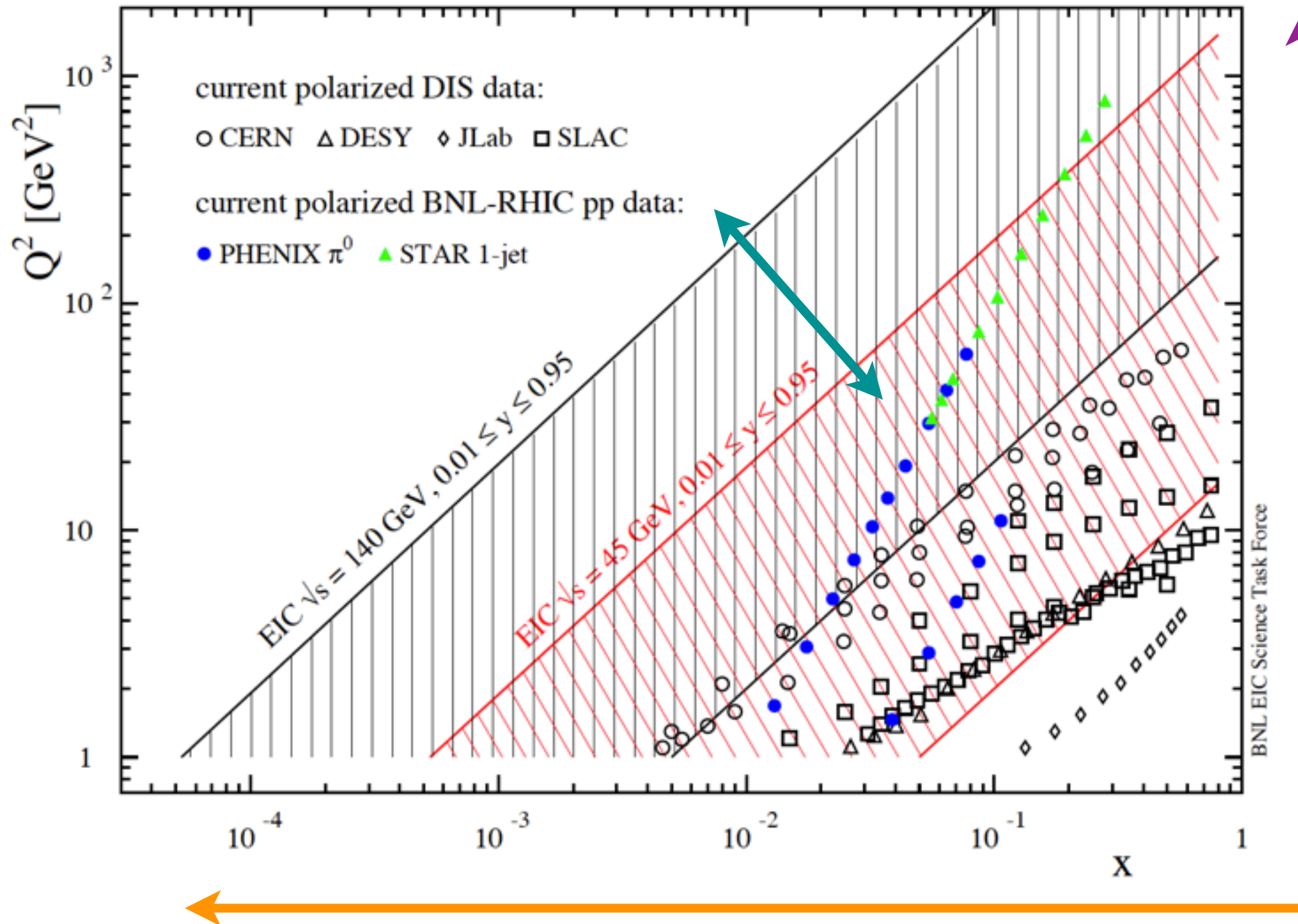 ▸ How much orbital motion?

DIS with **polarised** beams

- What is the impact of eRHIC?

  ▸ Perform global fit of existing data + eRHIC "data"

DIS with **polarised** beams
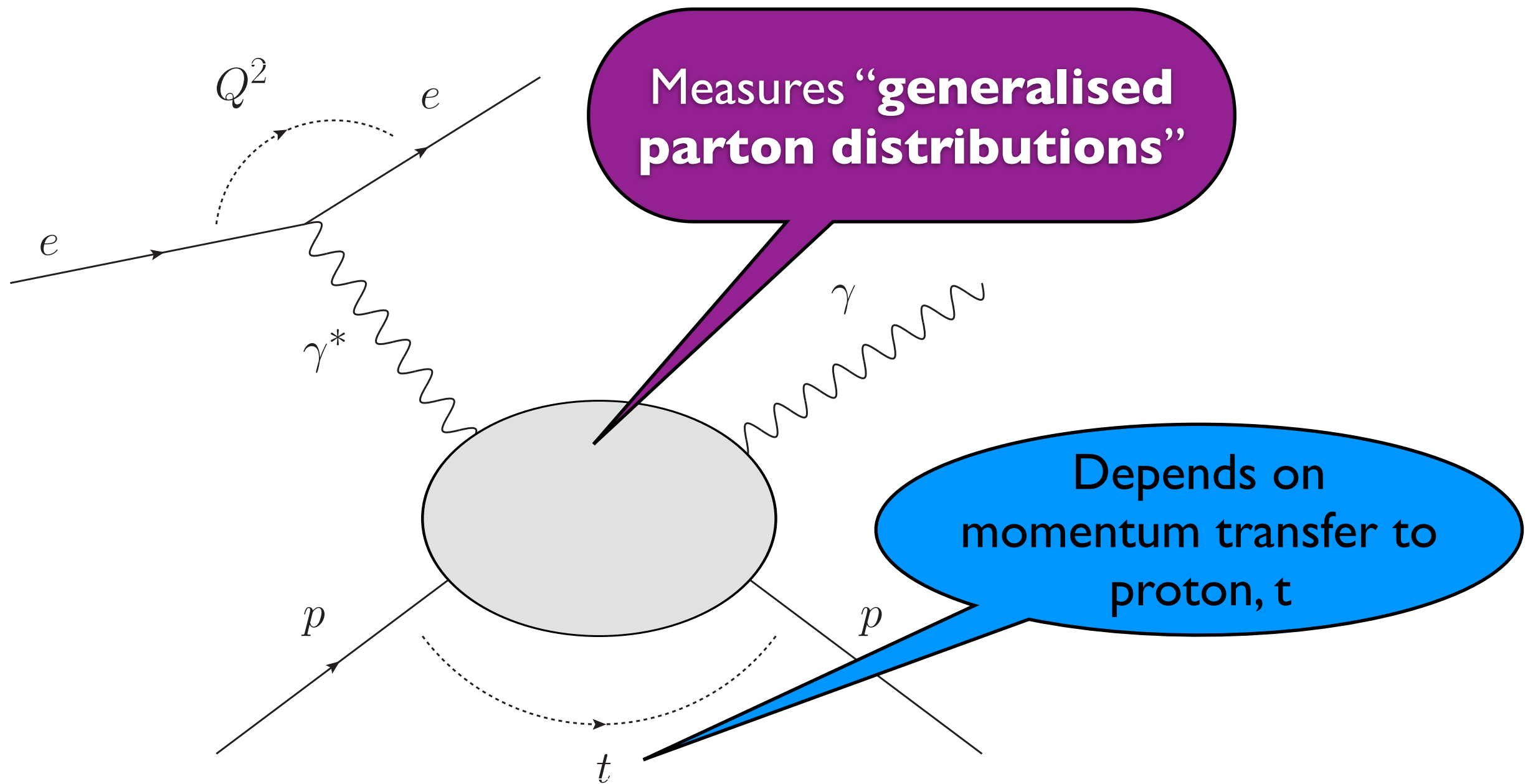

Integral over x → spin from gluons

eRHIC **kinematics**

Variable E
→ scan
x-Q² plane

Greatly
extended
reach to
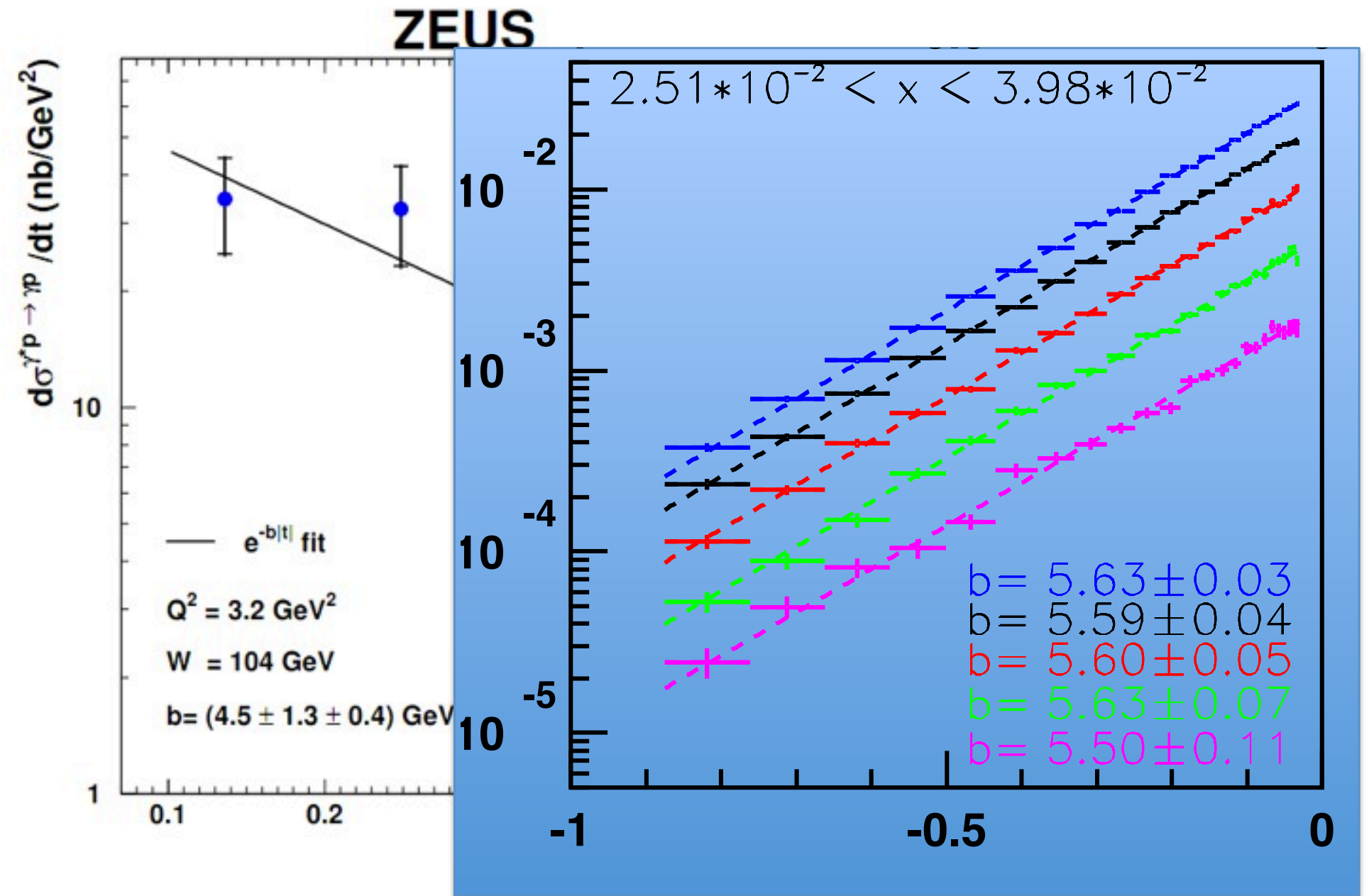both low x
& high Q²

2: Imaging

Deeply Virtual Compton Scattering

Fourier transform **GPDs** →
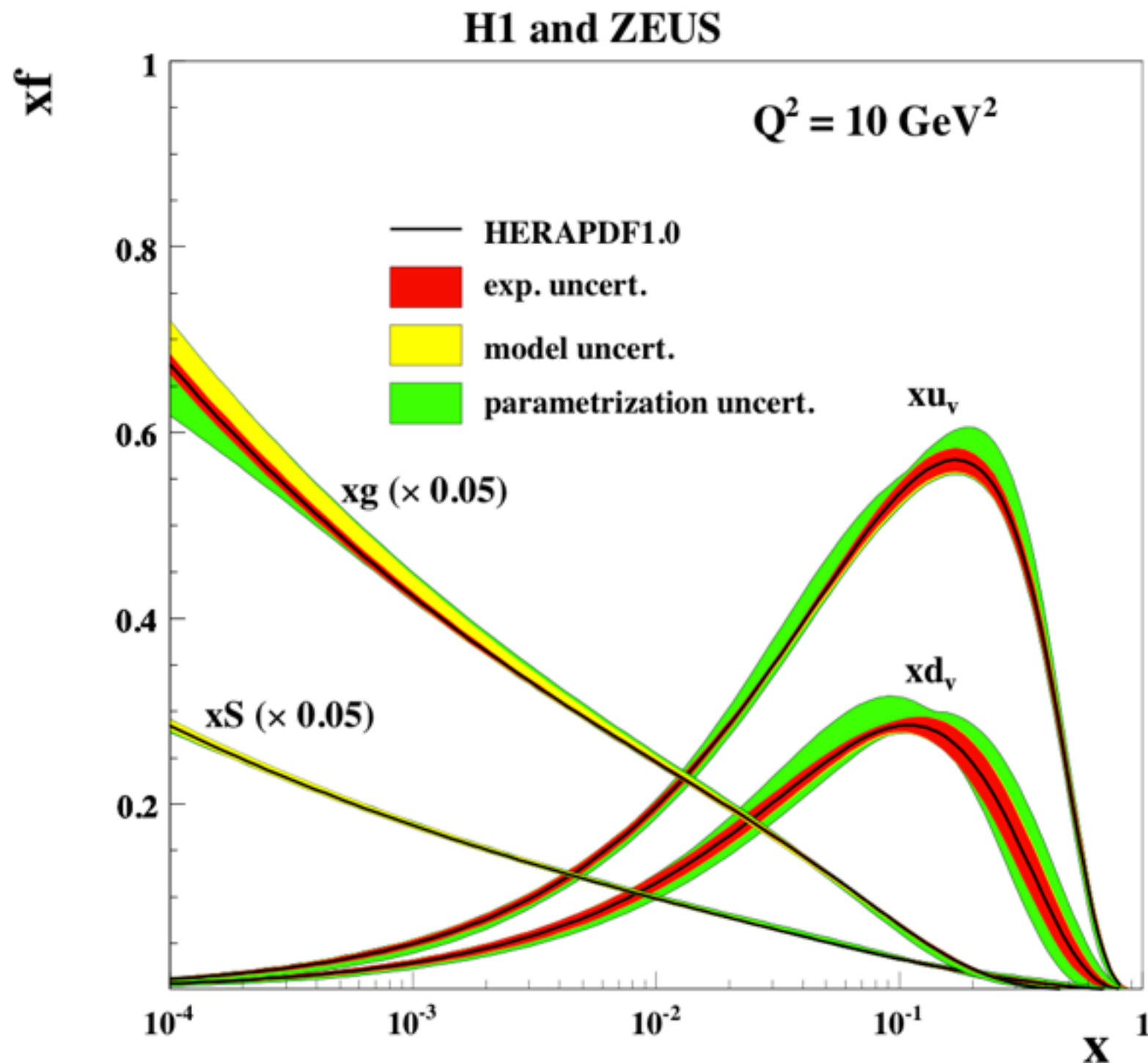**transverse spatial distribution: 3D imaging**

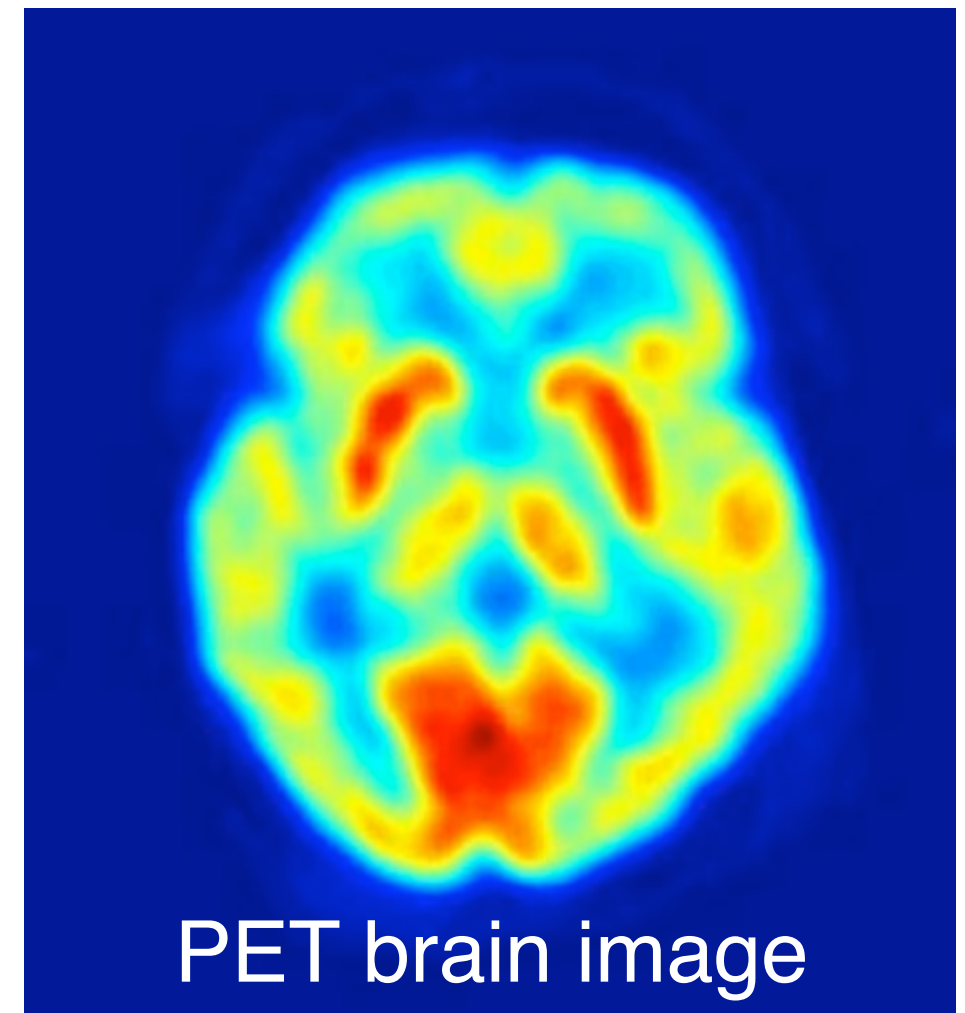# **D**eeply **V**irtual **C**ompton **S**cattering

Existing HERA data

eRHIC: high luminosity gives precision & fine binning

Nucleon **tomography**

H1 and ZEUS

$Q^2 = 10 \text{ GeV}^2$

HERAPDF1.0
exp. uncert.
model uncert.
parametrization uncert.

xu_v

$xg\ (\times 0.05)$
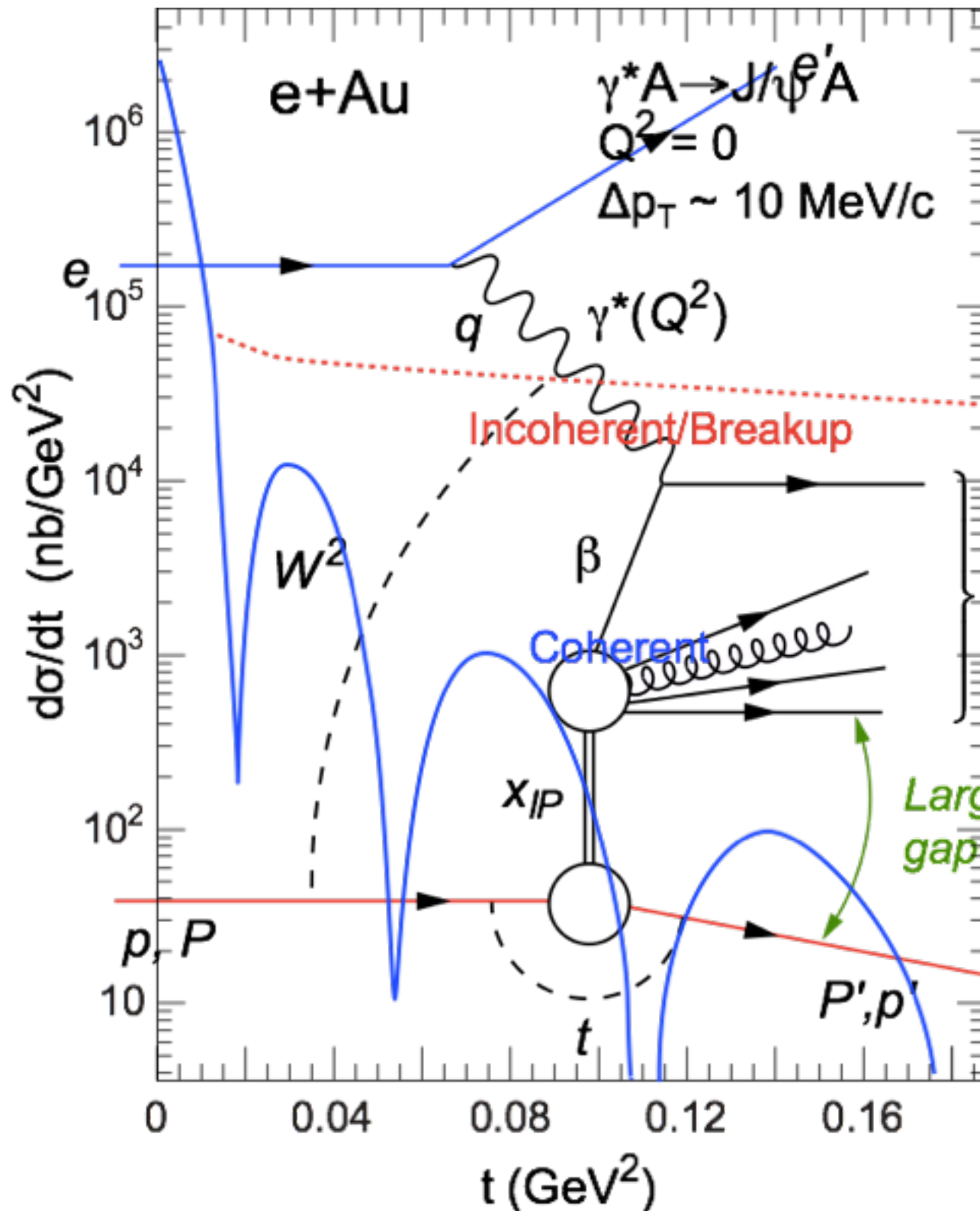
xd_v

$xS\ (\times 0.05)$

xf

x

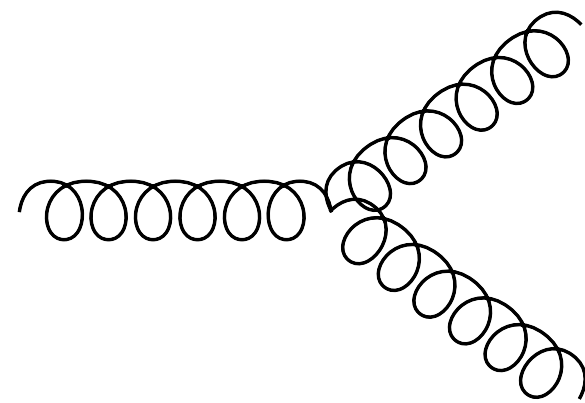## 2+1D imaging of the nucleon

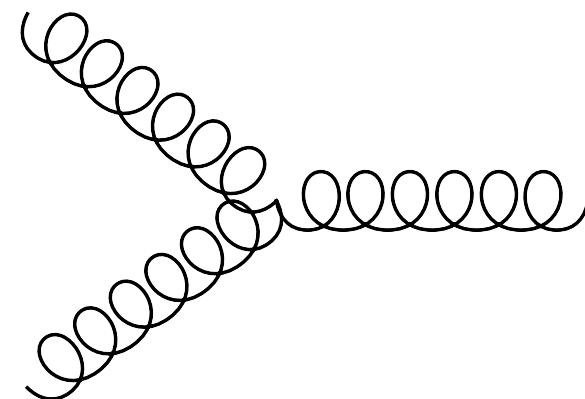
PET brain image

3: Strong colour fields

Nuclear **diffraction**

- dσ/dt is Fourier transform of b-density

- Large contribution to nuclear collisions ~30%
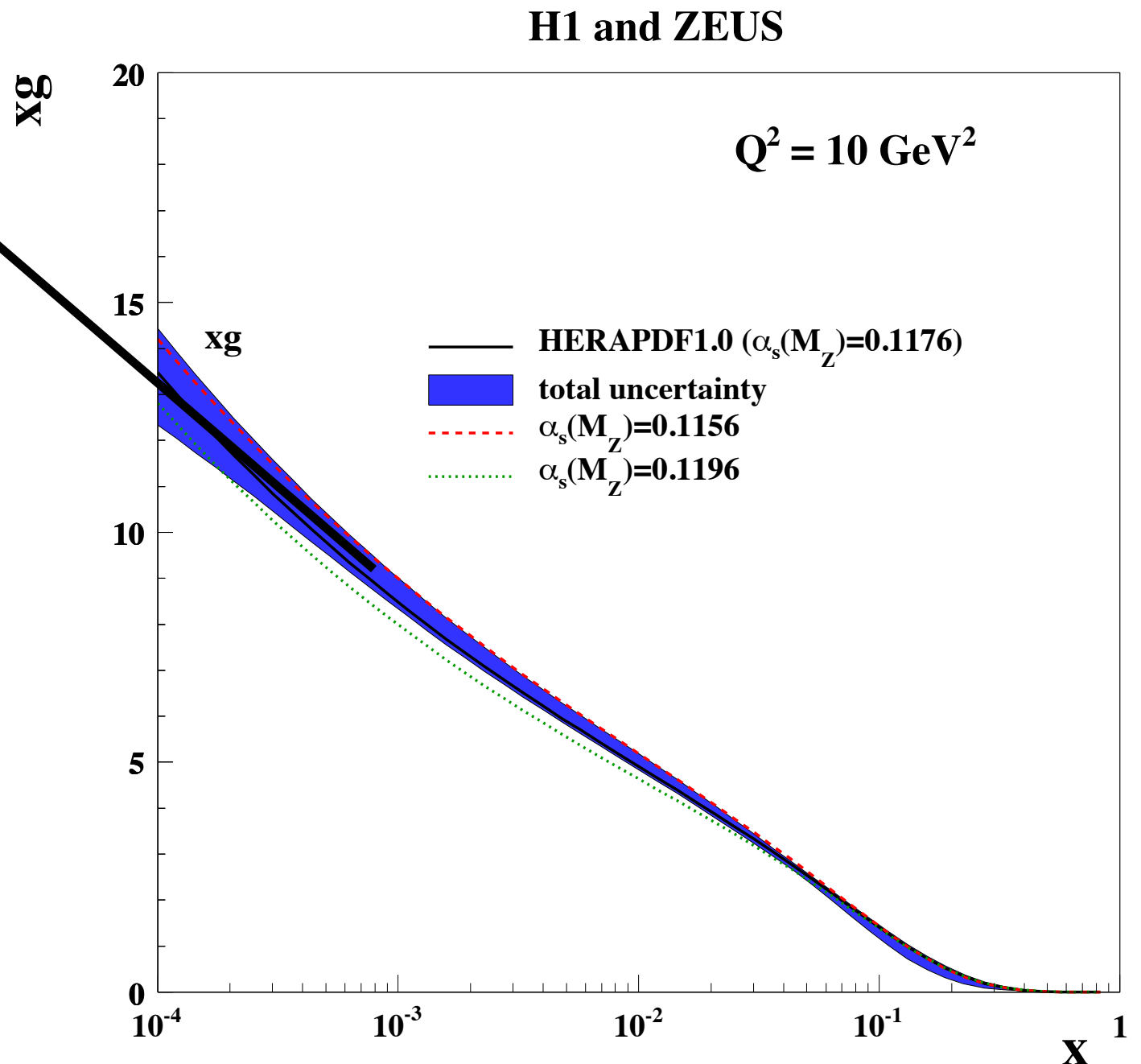
- Sensitive to *saturation*

Sensitive to **Saturation**

- Can't rise forever

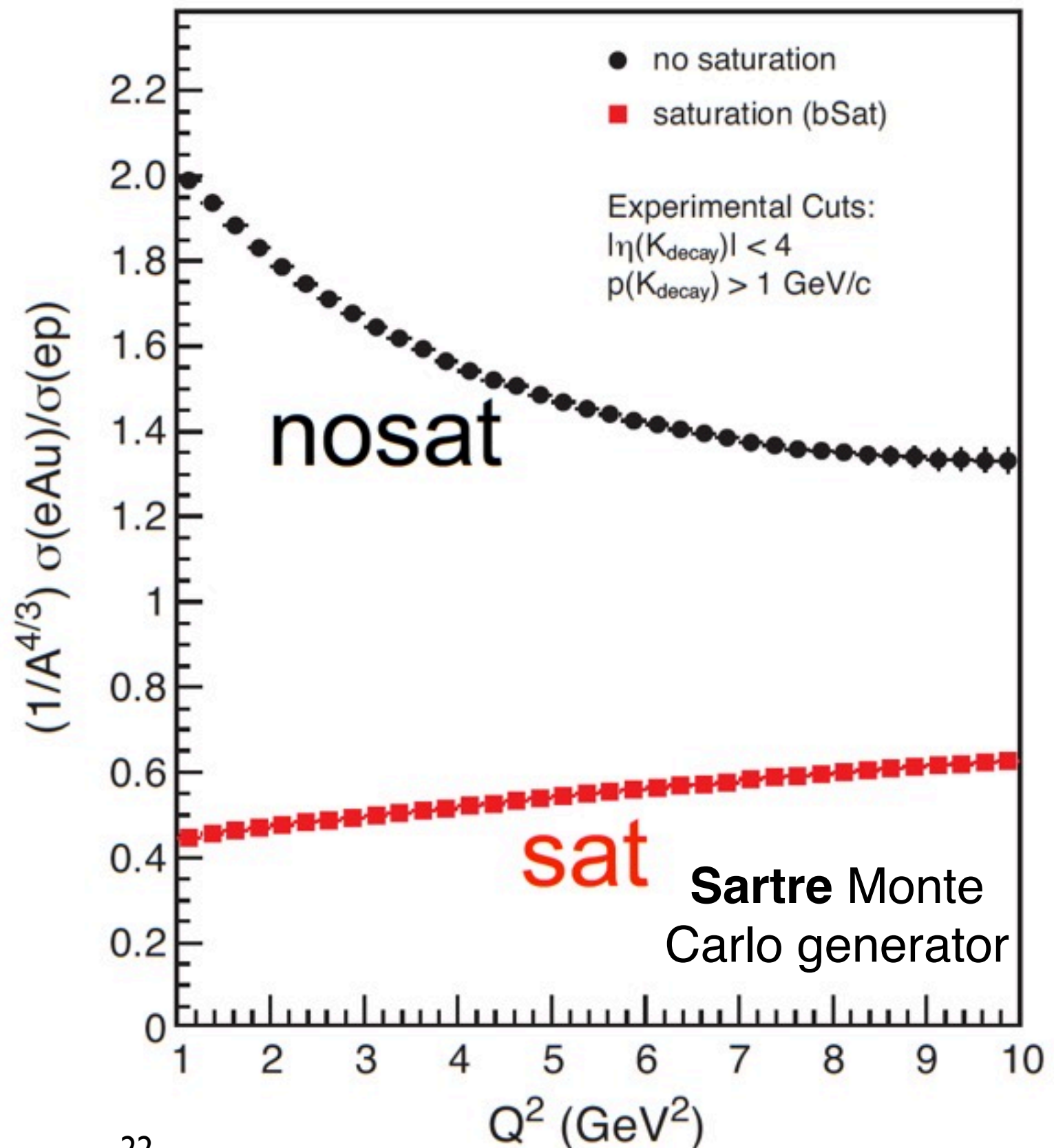- At some point density so high

  balanced by

"Saturation"
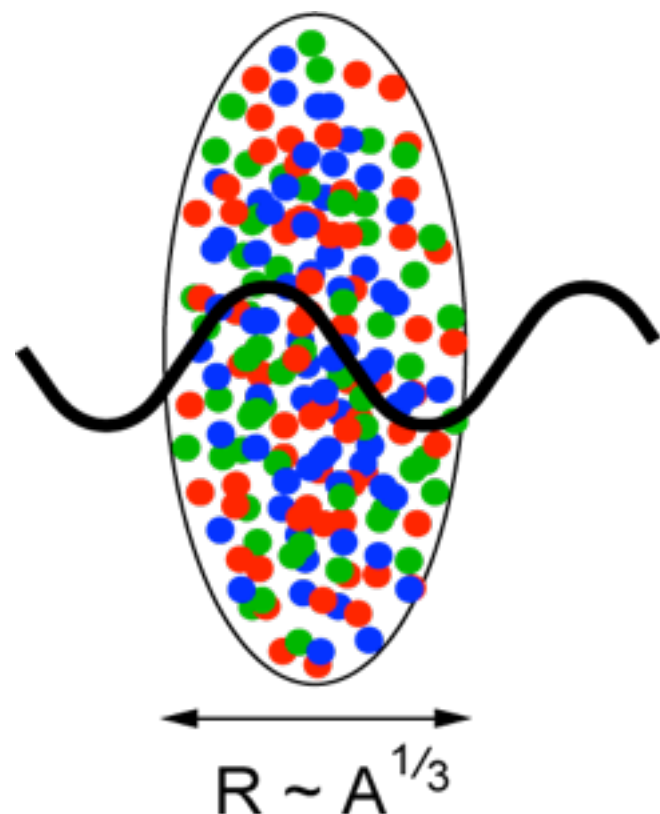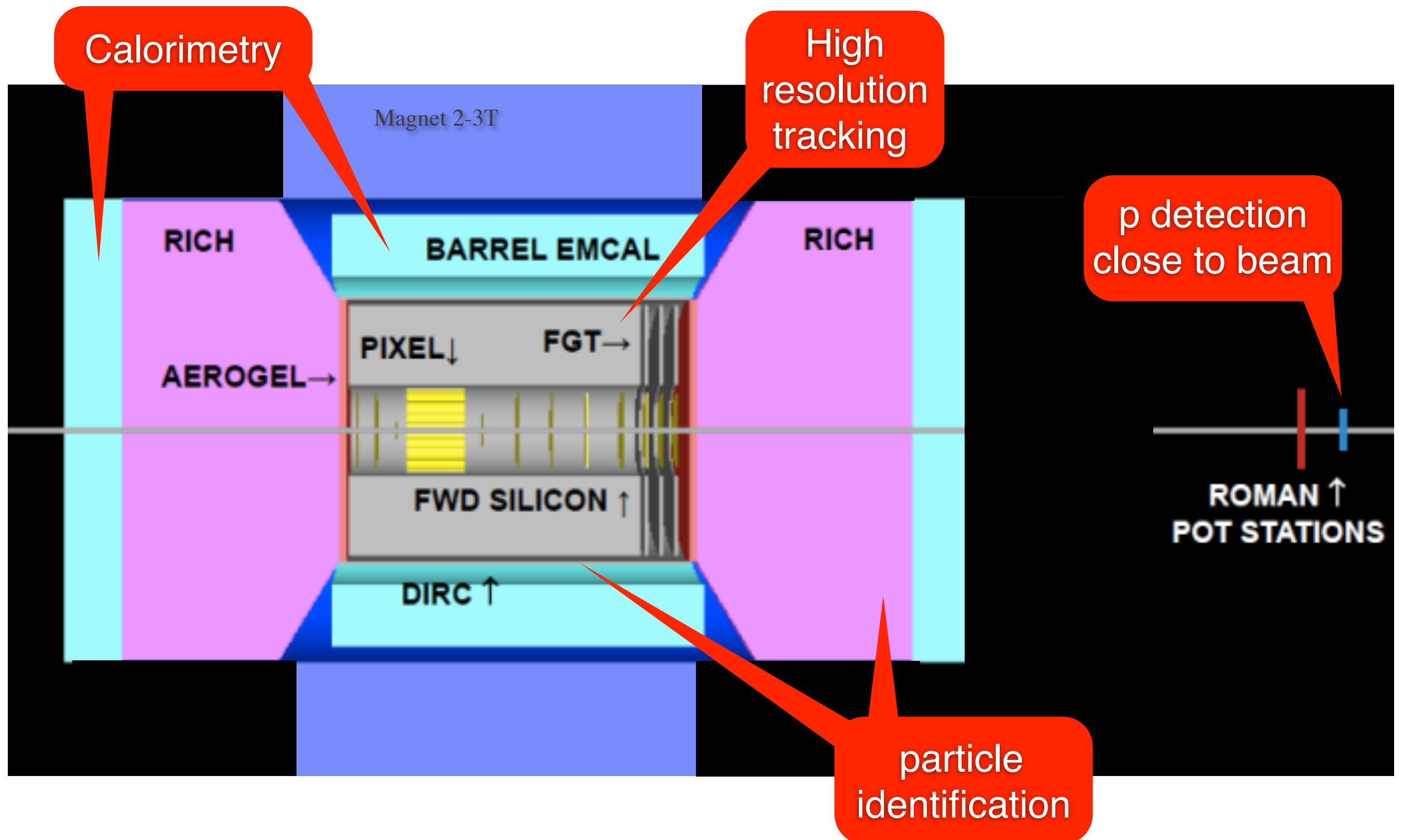
Exclusive Vector Meson Production

$$e + A \rightarrow e' + A' + VM$$

- Nuclei are an ideal laboratory for saturation

  ▸ higher g density

$R \sim A^{1/3}$

- no saturation
- saturation (bSat)

Experimental Cuts:
$|\eta(K_{decay})| < 4$
$p(K_{decay}) > 1$ GeV/c

nosat

sat

Sartre Monte Carlo generator

$(1/A^{4/3})\,\sigma(eAu)/\sigma(ep)$

Q^2 (GeV^2)

Detector

Summary

- eRHIC will provide
  - ‣ A broad, compelling physics programme
    - ‣ Much more than discussed here!
  - ‣ A state of the art detector
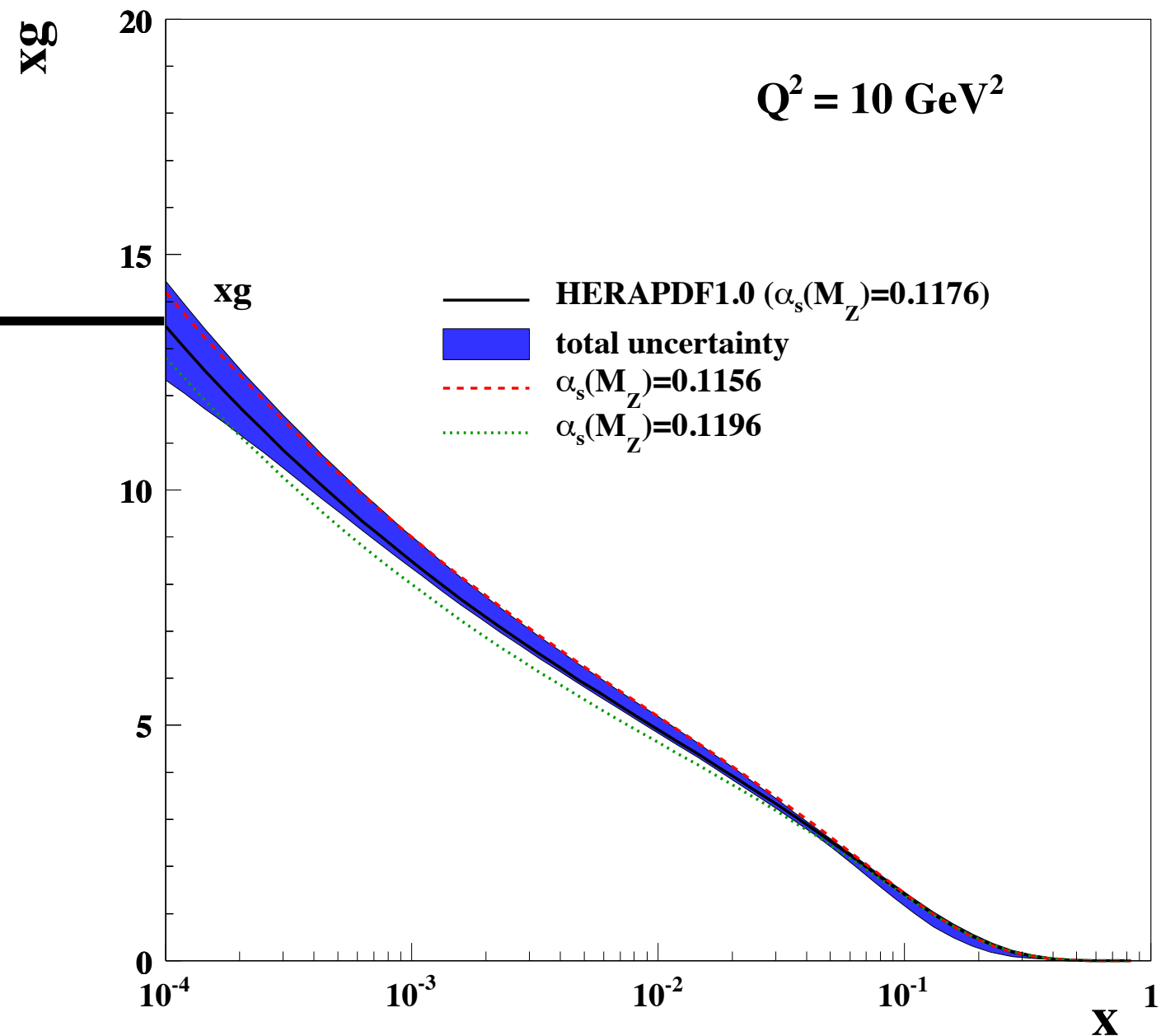 - ‣ A cost-effective route to an EIC

Sensitive to **Saturation**
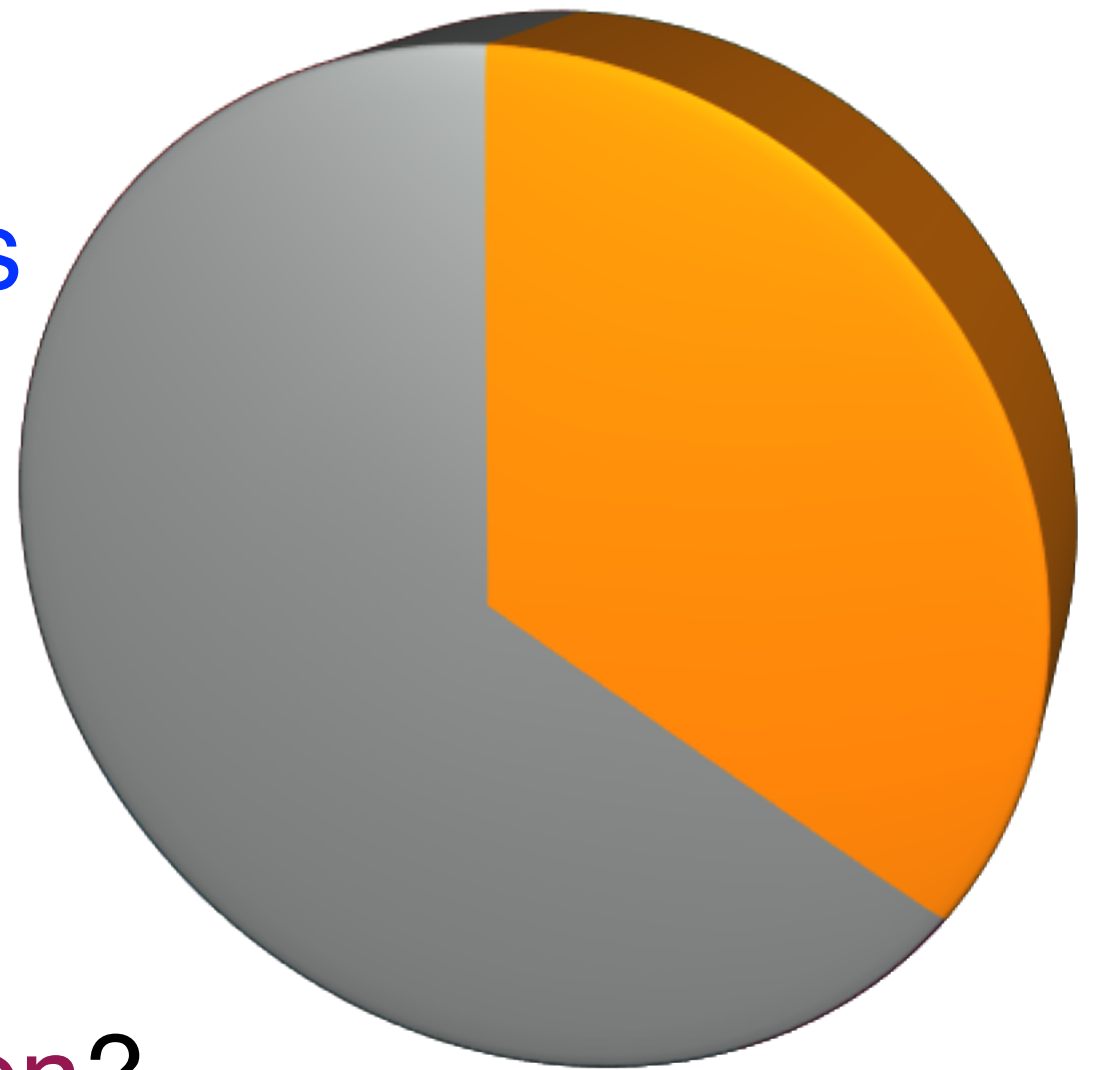
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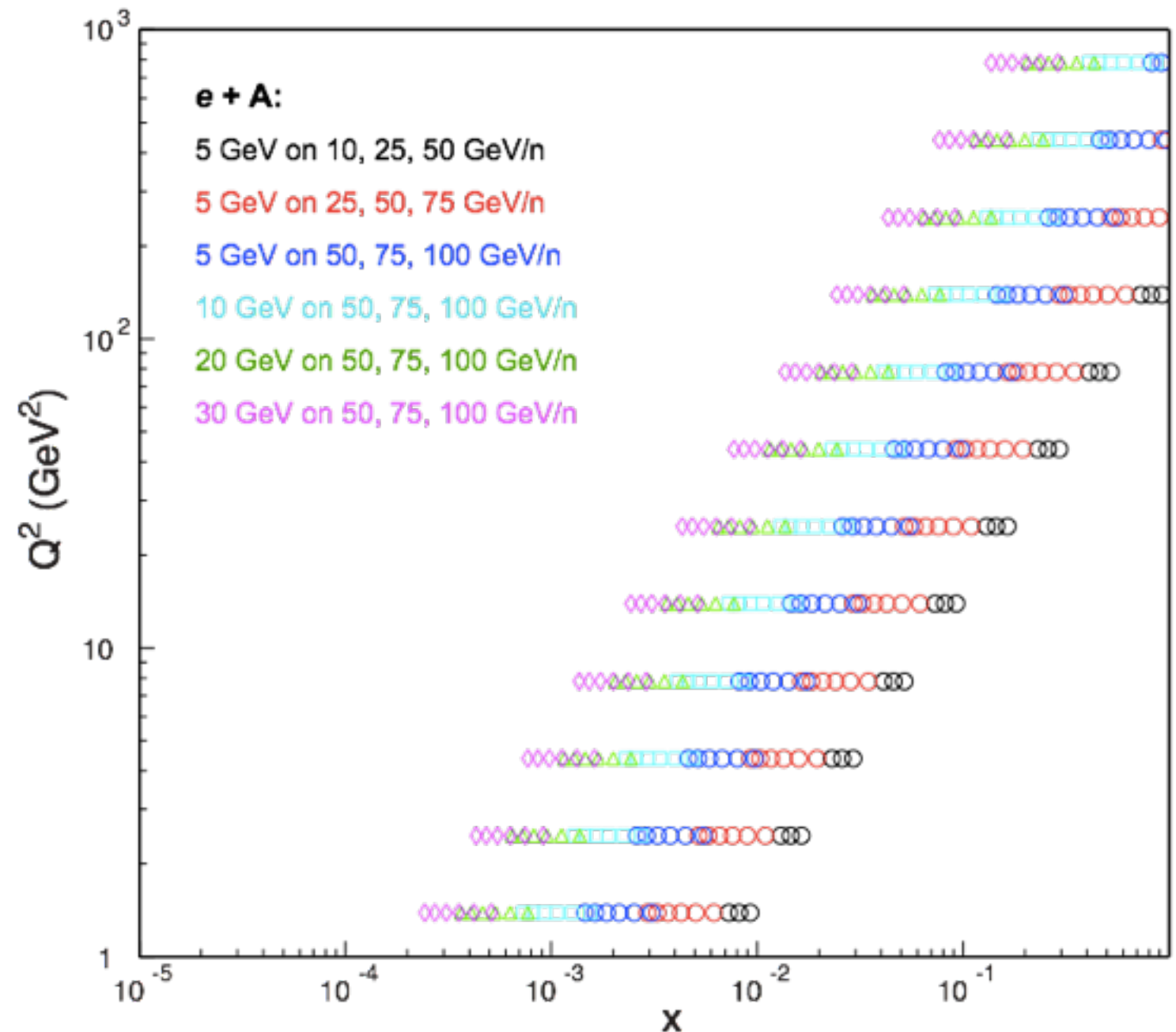 ‣ How much gluon spin?

  ‣ How much orbital motion?

Proton spin

Nuclear structure

$$\sigma_r^{DIS} = F_2(x, Q^2) - \frac{y^2}{1 + (1-y)^2} F_L(x, Q^2)$$

- *F_L*: nuclear gluon distribution

  ▸ nuclear wavefunction

- Requires variable energy

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Hadron imaging

DIS

$$\sigma_r \approx F_2(x, Q^2)$$

- F_2, F_L: "structure functions"

  ▸ F2 senstive to quark and (indirectly) gluon distributions.

  ▸ Parton Distribution Functions f(x, Q2)

  ▸ Well-measured by HERA

  ▸ FL directly sensitive to gluon distribution

H1 and ZEUS

$Q^2 = 10\ \text{GeV}^2$

xf

—— HERAPDF1.0
exp. uncert.
model uncert.
parametrization uncert.

xu_v

xg (× 0.05)

xd_v

xS (× 0.05)

10^{-4} 10^{-3} 10^{-2} 10^{-1} 1

x

Distribution in 1 dimension (x)